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(54) **SERVO MOTOR CONTROLLER.**

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Description

This invention relates to a servomotor control apparatus for controlling the positioning of a movable element of, for example, an industrial robot or NC machine tool.

A fully-closed loop-type control circuit is illustrated in Fig. 3 as an example of a CNC servo-control circuit. In the Figure, an information processing circuit X includes a CPU and a memory and forms a command signal for a servomechanism Y. The servomechanism Y is constituted by a comparator circuit a for comparing the command signal and a fed back position signal, a servo drive circuit b to which are inputted an error signal obtained by the comparator circuit a and a fed back velocity signal, a servomotor c, a velocity detector d for detecting the velocity of the servomotor c, and a linear scale e for position detection mounted on a mechanical load f such as a table.

The characterizing feature of a fully-closed loop servo system is that an arrangement in which the machine body is incorporated in the positioning servo loop is realized by mounting the position detector on the mechanical load f of the servomotor.

Fig. 4 is a block diagram of a servo system of this type, in which K denotes position gain, k_1 and k_2 gains, T_L disturbance, K_T a torque constant, J_m rotor inertia, and J_L load inertia.

The relationship between the position command and torque command of the servo system shown in Fig. 4 can be expressed by representing an integration term (Z^{-1}) by a transfer element subjected to a Z conversion (a pulse transfer function conversion), as shown in Fig. 5. In Fig. 5, MC(i) indicates a move command formed by an NC apparatus, VEL(i) indicates a servomotor velocity signal, and POS(i) represents an amount of movement of the machine in a sampling period T.

Besides using this fully-closed loop system, it is also possible to carry out positioning control by a semi-closed loop-type servo-control system which extracts a position signal from a servomotor output shaft in front of the mechanical load or from a ball screw shaft coupled to the servomotor output shaft. With this system, a comparatively inexpensive resolver, pulse encoder or the like is used as a position detecting element and it is possible to realize dynamic precision. However, since a mechanism-related error such as feed screw pitch error has a direct influence upon control precision, static precision with regard to position is poor in comparison with the former. Which servo-control system is used is decided at will by the user depending upon the type of position detecting element employed and to what degree of accuracy

the mechanical load is to be controlled. However, there are many cases in which an NC apparatus will make common use of both systems.

When the rotating direction of a servomotor changes in response to a command for changing the direction of movement of a table or arm, a response delay regarding the position command occurs in accordance with the servomotor velocity-torque characteristic shown in Fig. 2 since each axis of the mechanical load possesses a control error element ascribable to backlash or friction. In other words, the rotation of the servomotor of a predetermined axis approaches a stopped state when there is a reversal in the direction of rotation, and torque is no longer proportional to velocity before and after the operating quadrant reverses.

With the semi-closed loop servo-control system, a backlash command from the NC apparatus side is inputted to the servomechanism together with the position command, thereby correcting the servomotor position signal to improve upon the response delay when the direction of rotation reverses. However, as described in connection with Fig. 3, the fully-closed loop servo-control system is arranged so that the mechanical load is included in the positioning servo loop, and a backlash component is contained in the position signal obtained from the linear scale 3. As a result, the servo-control system position signal cannot be corrected by the backlash correction outputted from the NC apparatus side. In consequence, the backlash correction command cannot be used commonly by the same NC apparatus in both the semi-closed loop servo-control system and fully-closed loop servo-control system. Accordingly, there is a decline in the utilization efficiency of the NC apparatus and the response delay at the time of the reversal in direction cannot be ameliorated with regard to the machine in the fully-closed loop servo-control system.

The present invention has been devised in order to solve the aforementioned problem and its object is to provide a servomotor control apparatus which, by forming a torque command that takes frictional resistance into consideration, is suitable for application to both a semi-closed loop servo-control system and a fully-closed loop servo-control system.

The invention employs a correction signal having a polarity depending upon backlash as does JP-A-60-116004, which discloses a servomotor control apparatus according to the preamble of the attached claim 1.

According to the present invention there is provided a servomotor control apparatus for controlling movement of a mechanical load by a servomotor in dependence upon a position command, a detected position signal produced by position

detecting means for detecting position of the mechanical load, a backlash correction command for backlash at the mechanical load, and a correction signal having a polarity which depends upon the backlash correction command, characterised in that said correction signal is produced by a correcting means which discriminates, on the basis of said backlash correction command, a timing at which an operating quadrant of the mechanical load reverses, and then forms said correction signal as offset data corresponding to frictional resistance of the mechanical load, to be employed when the quadrant reverses to correct a torque command formed in dependence upon said position command and said detected position signal, there being control means for driving and controlling the servomotor by the corrected torque command.

Accordingly, with regard to the fully-closed loop-type servo system, the servomotor control apparatus of the present invention inputs a backlash correction command and data indicative of the servomotor operating quadrant together with an ordinary position command, and outputs a torque command, which corresponds to frictional torque of the machine at the time of the quadrant reversal, to the servomotor as offset data. As a result, a response delay regarding the position command at the time of the quadrant reversal can be ameliorated. In addition, a backlash correction command from the same NC apparatus can be used for control in servo-control systems of both the semi-closed and fully-closed loop type.

Brief Description of the Drawings

Figs. 1(a), (b) are a block diagram and flowchart illustrating the general arrangement of the present invention, Fig. 2 is view illustrating a velocity-torque characteristic, Fig. 3 is a circuit diagram of a fully-closed loop-type servomotor control apparatus, and Figs. 4 and 5 are block diagrams of a servo-control system.

An embodiment of the present invention will now be described in detail with reference to the drawings.

Fig. 1(a) is a block diagram illustrating the general arrangement of the invention. In the Figure, an NC apparatus outputs a position command MC(i) and a backlash correction command (BLi) to a servo-control system. The position command MC(i) is inputted to a comparator B₁, which compares the position command MC(i) and a position signal POS(i) to form an error signal E₁. The error signal E₁ is multiplied by the position gain K and the product is inputted to a comparator B₂ as a velocity command E₂. The comparator B₂ compares the velocity command E₂ with the servomotor velocity signal VEL(i) to form an error signal E₃. The

error signal E₃ is outputted to a comparator B₄ via a comparator B₃, integration term Z⁻¹ and gain k₁, and is operated on by the velocity signal VEL(i) fed back to the comparator B₄ via gain k₂. The comparator B₄ outputs a torque command for the servomotor.

A backlash correction flag BLF(i) formed from the backlash correction command BL is inputted to a correction circuit A. If the velocity-torque characteristic of the servomotor is as shown in Fig. 2, the correction circuit A receives the correction flag BLF(i) inputted as quadrant data regarding the backlash correction command, and there is a reversal in the operating quadrant, which is detected for each axis, of the movable element. At this time the torque correction command FR(i) corresponding to stored frictional torque is outputted. More specifically, a torque command corresponding to frictional torque of the machine is applied as offset data, as shown in the operating flow of Fig. 1(b), in accordance with operating region data at the time the direction of rotation reverses.

That is, offset data FR(i) is formed and inputted to the comparator B₄. The offset data FR(i) is as follows, with reference to Fig. 1(b):

$$(1) \quad FR(i) = -Fa$$

for the third quadrant [BLF(i) < 0]; (where Fa represents a preset frictional torque of the machine) and

$$(2) \quad FR(i) = Fa$$

for the first quadrant [BLF(i) > 0].

In the semi-closed loop-type servo-control system, the backlash correction command BL(i) is inputted directly to the comparator B₁ or B₂ to correct the position signal. In the fully-closed loop-type servo-control system, the mechanical load itself is disposed in the positioning servo loop, as mentioned above. As a result, a backlash component is contained in the position signal, so that the position signal itself cannot be corrected. Accordingly, offset data the polarity of which is decided by the backlash correction flag BLF(i) based on the quadrant data of the velocity-torque characteristic is inputted by an open loop at the position at which the torque command in the servo loop is formed, as shown in Fig. 1(a). The reason for this is that since the move command issued in the servo system usually is substantially zero at the time of the reversal in the direction of rotation, the polarity of the torque command cannot be discriminated from the polarity of the move command. Thus, an improvement in response delay is achieved by forming the torque command at the time of the reversal in direction from the quadrant data regarding

the backlash correction command for correcting the velocity-torque characteristic.

The servomotor control apparatus of the present invention can be applied to a servo system adapted to perform feedback of a machine position and not servomotor position in response to a position command.

Claims

1. A servomotor control apparatus for controlling movement of a mechanical load by a servomotor (C) in dependence upon a position command (MC(i)), a detected position signal (POS(i)) produced by position detecting means (e) for detecting position of the mechanical load, a backlash correction command (BL(i)) for backlash at the mechanical load, and a correction signal (FR(i)) having a polarity which depends upon the backlash correction command (BL(i)), characterised in that said correction signal (FR(i)) is produced by a correcting means (A) which discriminates, on the basis of said backlash correction command (BL(i)), a timing at which an operating quadrant of the mechanical load reverses, and then forms said correction signal (FR(i)) as offset data corresponding to frictional resistance of the mechanical load, to be employed when the quadrant reverses to correct a torque command formed in dependence upon said position command (MC(i)) and said detected position signal (POS(i)), there being control means for driving and controlling the servomotor by the corrected torque command.
2. A servomotor control apparatus according to claim 1, wherein said position signal detecting means (e) comprises a linear scale.
3. A servomotor control apparatus according to claim 1 or 2, wherein said correcting means (A) rewritably stores offset data corresponding to a frictional resistance value peculiar to each axis of the mechanical load.
4. A servomotor control apparatus according to any preceding claim, wherein said control means is either a semi-closed loop servo system or a fully-closed loop servo system, and the corrected torque command is formed by said backlash correction command (BL(i)) or by offset data from said correcting means (A).
5. A servomotor control apparatus according to any preceding claim, wherein the mechanical load is a machine tool or an industrial robot having a plurality of servo systems.

Patentansprüche

1. Servomotorsteueranordnung zur Steuerung der Bewegung einer mechanischen Last durch einen Servomotor (C) in Abhängigkeit von einem Positionsbefehl (MC (i)), einem durch eine Positionsdetektoreinrichtung (e) zum Detektieren der Position der mechanischen Last erzeugten detektierten Positionssignal (POS(i)), einem Spielkorrekturbefehl (BL(i)) für ein Spiel an der mechanischen Last, und einem Korrektursignal (FR(i)) mit einer Polarität, die von dem Spielkorrekturbefehl (BL(i)) abhängt, **dadurch gekennzeichnet**, daß das Korrektursignal (FR(i)) durch eine Korrekturereinrichtung (A) erzeugt ist, die auf der Basis des Spielkorrekturbefehls (BL(i)) einen Zeitpunkt bestimmt, zu welchem ein Arbeitsquadrant der mechanischen Last wechselt, und dann das Korrektursignal (FR(i)) als mit einem Reibungswiderstand der mechanischen Last korrespondierende Verschiebedaten bildet, die anzuwenden sind, wenn der Quadrant zur Korrektur eines in Abhängigkeit von dem Positionsbefehl (MC(i)) und dem detektierten Positionssignal (POS(i)) gebildeten Drehmomentbefehls wechselt, wobei eine Steuereinrichtung zum Antrieb und zur Steuerung des Servomotors durch den korrigierten Drehmomentbefehl vorgesehen ist.
2. Servomotorsteueranordnung nach Anspruch 1, **dadurch gekennzeichnet**, daß die Positionssignaldetektoreinrichtung (e) eine lineare Skala aufweist.
3. Servomotorsteueranordnung nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, daß die Korrekturereinrichtung (A) Verschiebedaten, die mit einem jeder Achse der mechanischen Last eigenen Reibungswiderstandswert korrespondieren, wiedereinschreibbar speichert.
4. Servomotorsteueranordnung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet**, daß die Steuereinrichtung entweder ein halbgeschlossenes Schleifenservosystem oder ein ganz geschlossenes Schleifenservosystem ist, und daß der korrigierte Drehmomentbefehl aus dem Spielkorrekturbefehl (BL(i)) oder durch Verschiebedaten aus der Korrekturereinrichtung (A) gebildet ist.
5. Servomotorsteueranordnung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet**, daß die mechanische Last eine Werkzeugmaschine oder ein Industrieroboter mit mehreren Servosystemen ist.

Fig. 1(a)

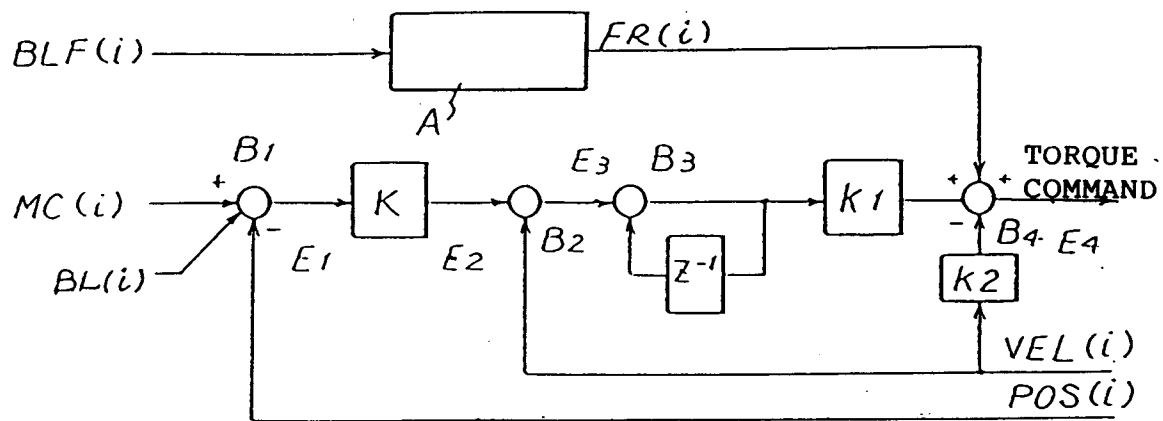


Fig. 1(b)

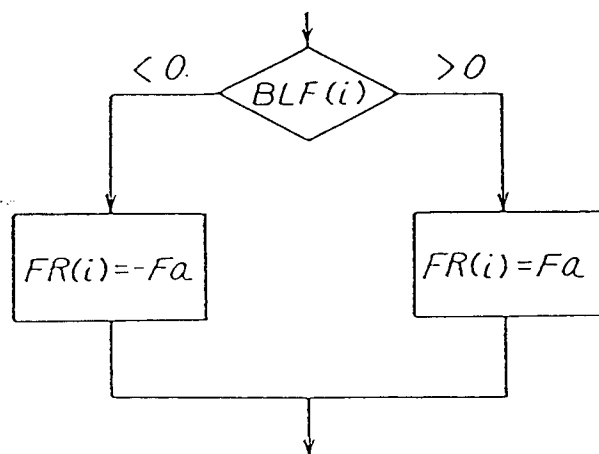


Fig. 2

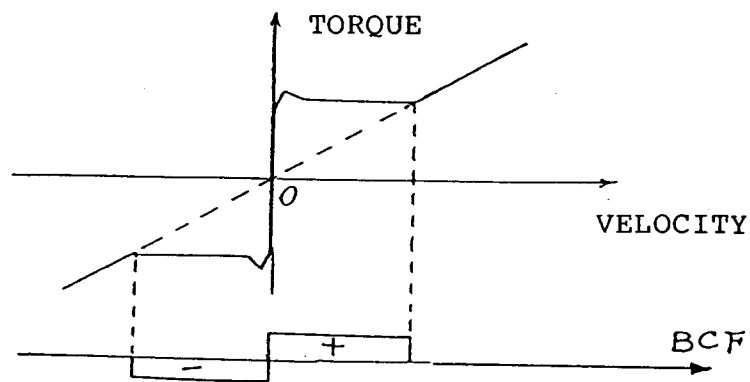


Fig. 3

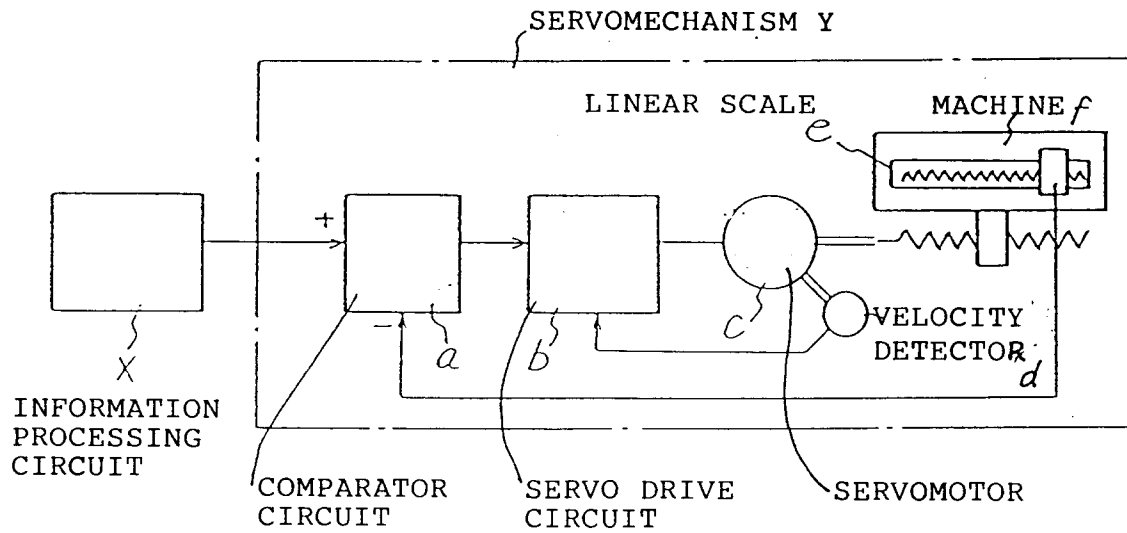


Fig. 4

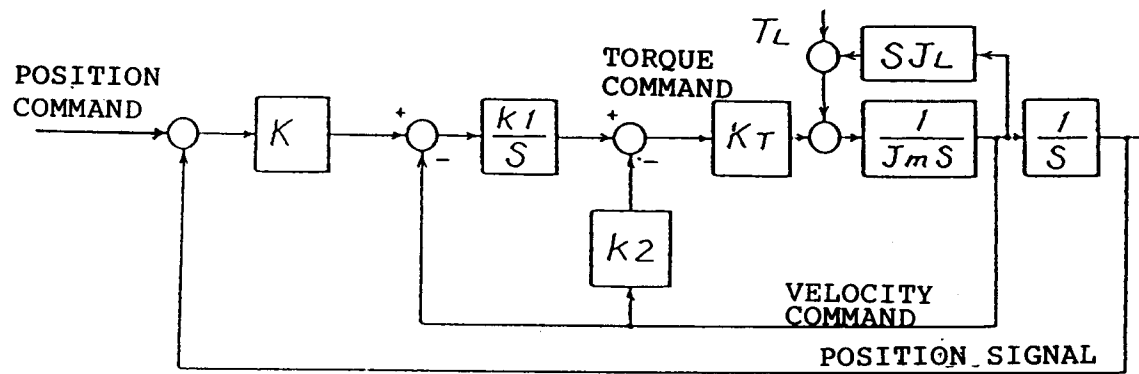


Fig. 5

